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Research and Development Technical Report

ECOM

HIGH VOLTAGE BREAKDOWN STUDY

ADDENDUM TO FINAL REPORT

Prepared by:

ION PHYSICS CORPORATION

BURLINGTON, MASSACHUSETTS

MARCH 1970

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Technical Report ECOM March 1970

HIGH VOLTAGE BREAKDOWN STUDY

Addendum to Final Report

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1. INTRODUCTION

Experimental work of the "High Voltage Voltage Breakdown Study" was carried out from 15 November 1965 to 15 November 1969. The details of experimental procedures and results have been reported in 19 Quarterly Progress Reports which cover the period to 15 August 1969. The results of the final quarter have been summarized in the Final Report, but no formal 20th Quarterly Progress Report was required. In order that the data obtained in this final quarter be available on a par with that of previous quarters, this addendum to the final report contains additional data from the period 15 August 1969 to 15 November 1969. A brief discussion of this data is included.

2. ENERGY CONDITIONING STUDY

The extension of the energy conditioning study to a detailed investigation of the effect of anode material under high energy discharges has been presented in Section 10.9.

In this addendum the details of four treatments with the following electrode combinations are presented:

	Anode	Cathode
Figure 1	304 Stainless Steel	Aluminum
Figure 2	Lead	Ti-7Al-4Mo
Figure 3	Molybdenum	Ti-7Al-4Mo
Figure 4	Tungsten	Ti-7Al-4Mo

The treatments with Molybdenum and Tungsten anodes used disks of the metal 0.25 inches thick mounted on stainless steel electrodes. The edges were radiused so that a uniform field would result in the gap. These were used due to unavailiability of larger sizes of molybdenum and tungsten. The predicted maximum breakdown voltage for these metals was somewhat higher than was actually obtained (see Section 10.9). This disparity is thought to be due to long

term general heating of the anode. The 0.25 inch thick by 2" diameter disks were heated by prebreakdown field emission currents to a red heat in times short compared to those necessary to significantly raise the average temperature of the massive 4" diameter electrodes used in other tests. Figure 5 shows this excessive heating of the anode -- the active disk is red hot while the large stainless steel mounting electrode is relatively cold. Thus it can be concluded that cooling of the anode (either by external means or by virtue of a much larger mass) would result in maximum breakdown voltages much closer to those predicted.

The treatment with a lead anode had the predicted low level of maximum breakdown voltage. Additional tests with this electrode pair explored breakdown voltage as a function of gap from .25 to 4.5 cm. It was found that under low energy discharges the breakdown voltage at any gap in this range was well defined and repeatable. The dependence on the square root of the gap is given in Figure 6. As can be seen the fit is extremely good from 1.0 cm to 4.5 cm.

3. BARIUM CONTAMINATION STUDY

Detailed results of treatments discussed in Section II of the Final report are presented in Figures 7 through 9.

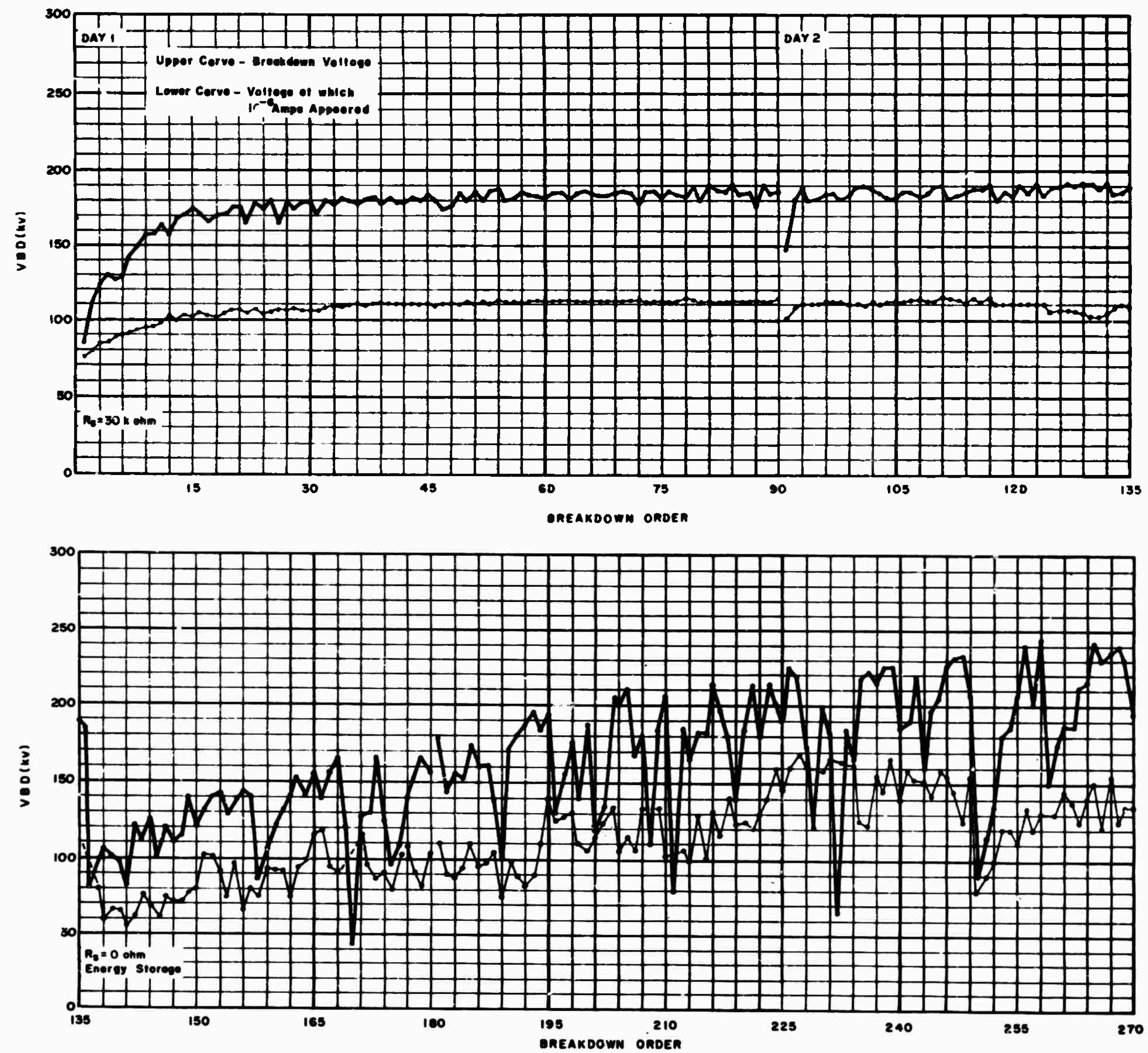


Figure 1. Conditioning Curve for 4-Inch Diameter Bruce Profile Electrodes — Stainless Steel (304) Anode and Aluminum Cathode at .75 cm Gap.

1-4497

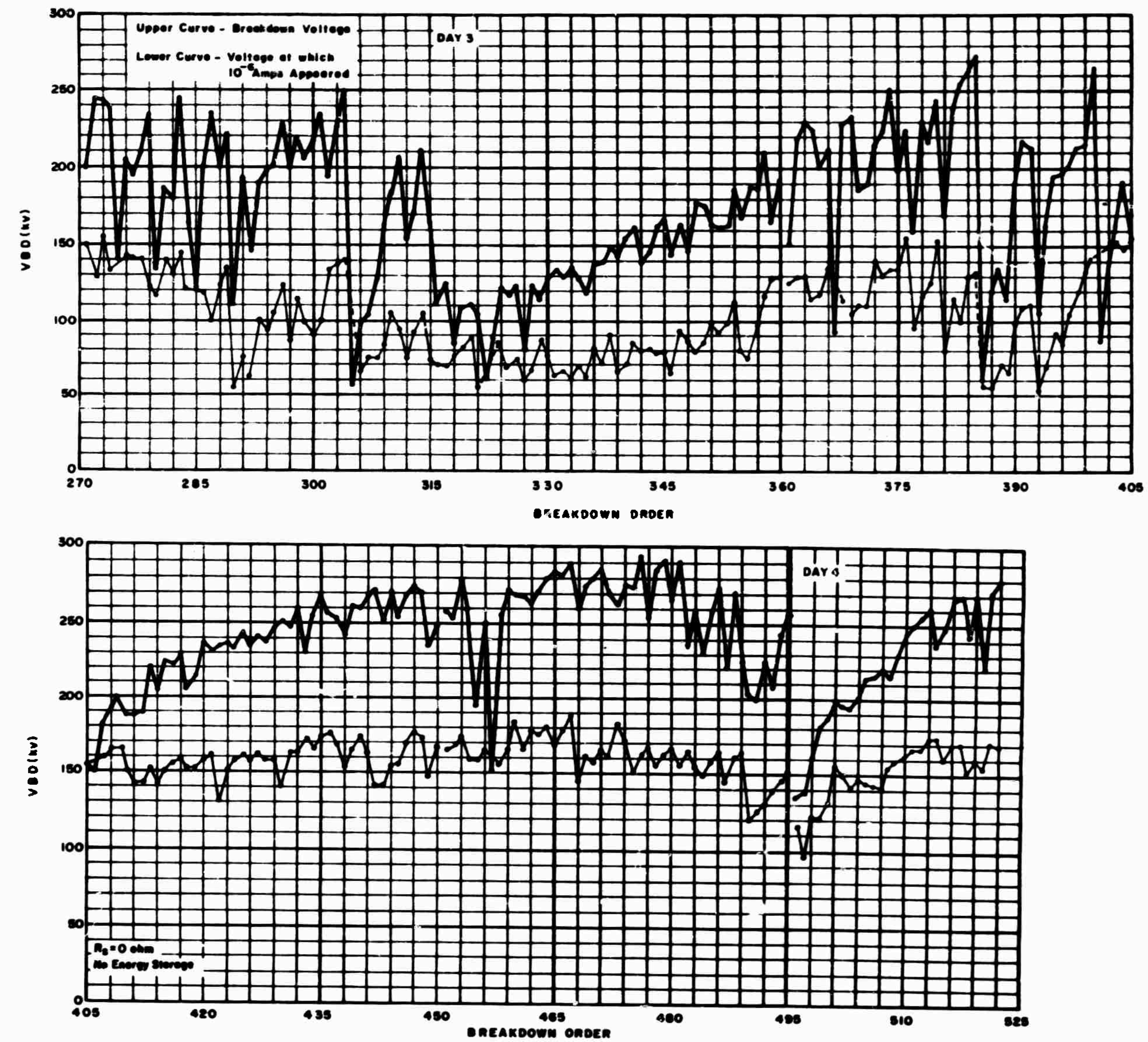


Figure 1. Continued.

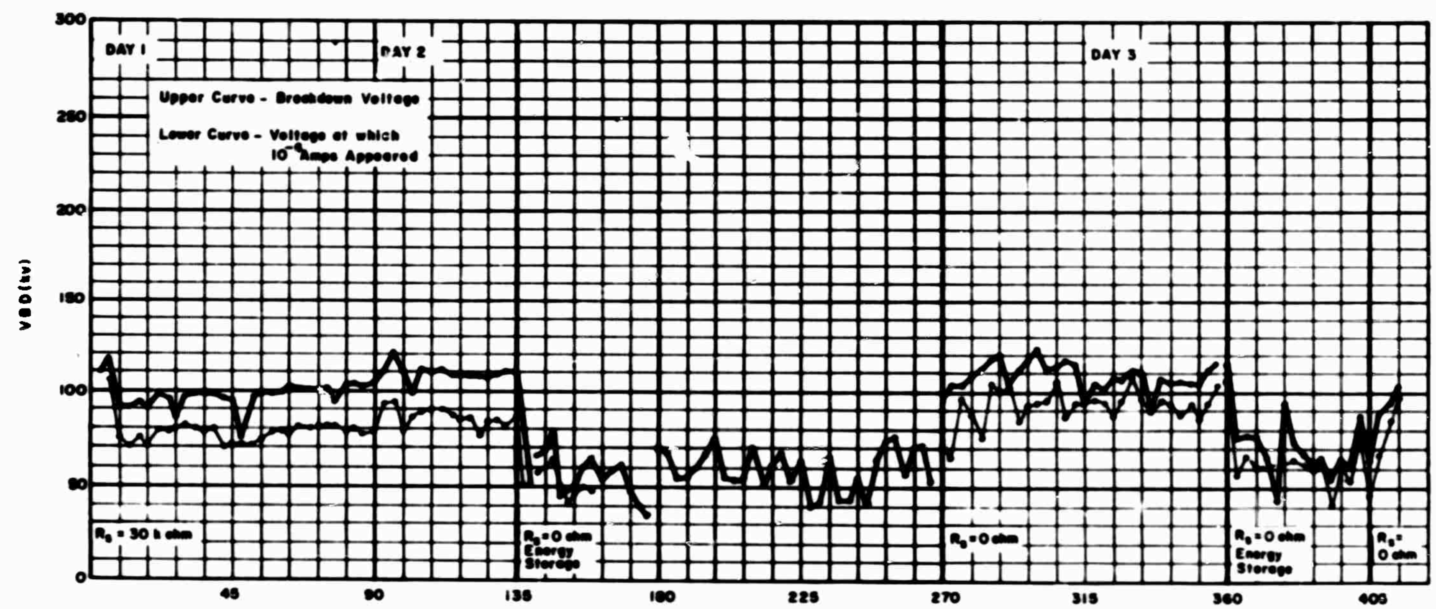


Figure 2. Conditioning Curve - 4-Inch Diameter Bruce Profile Electrodes Lead Anode and Ti-7 Al - 4 Mo Cathode at .75 cm Gap.

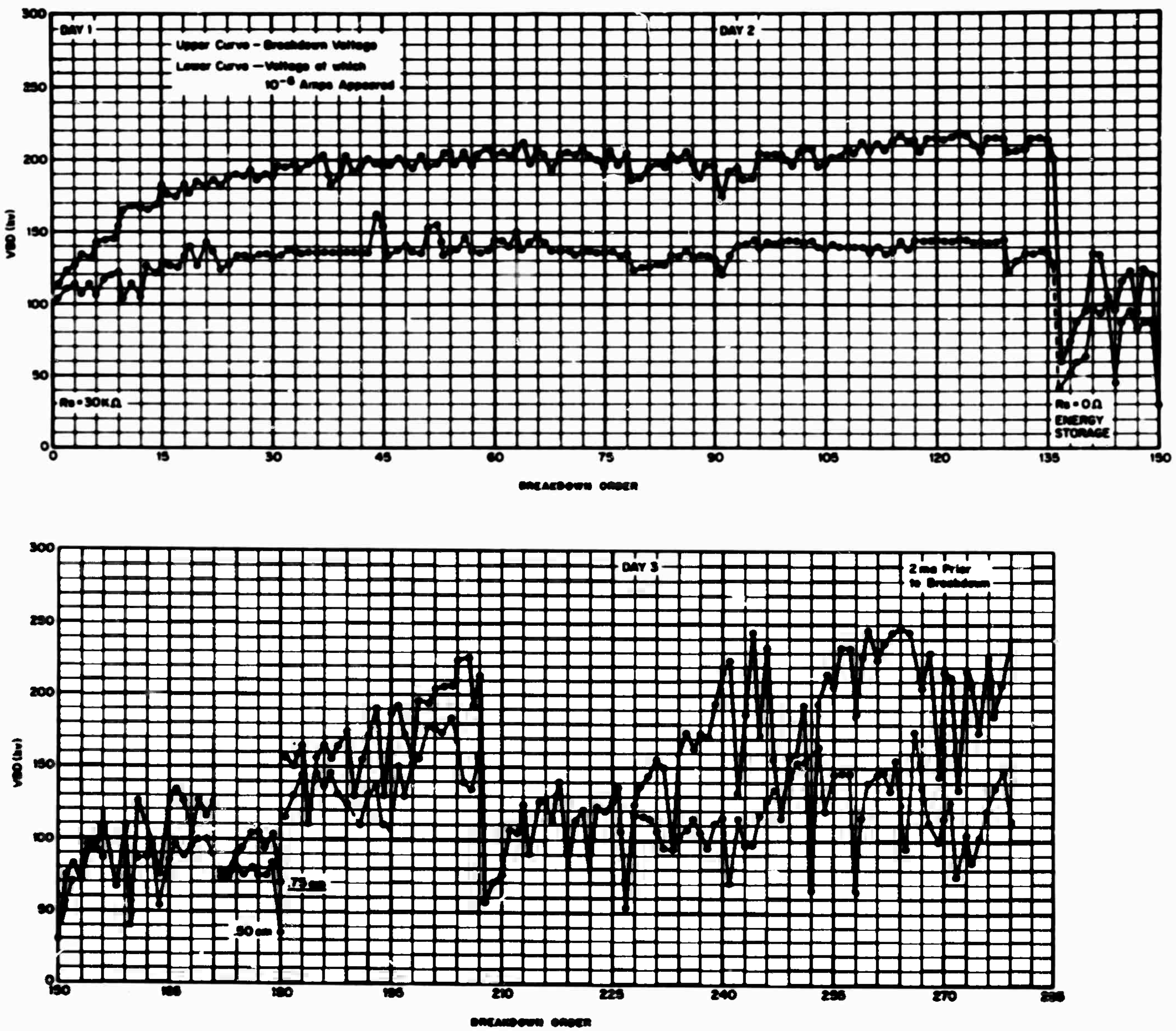


Figure 3. Conditioning Curve - Molybdenum Anode and Ti-7 Al - 4 Mo Cathode 2-Inches Diameter Uniform Field Electrodes at .75 cm Gap.

1-4499

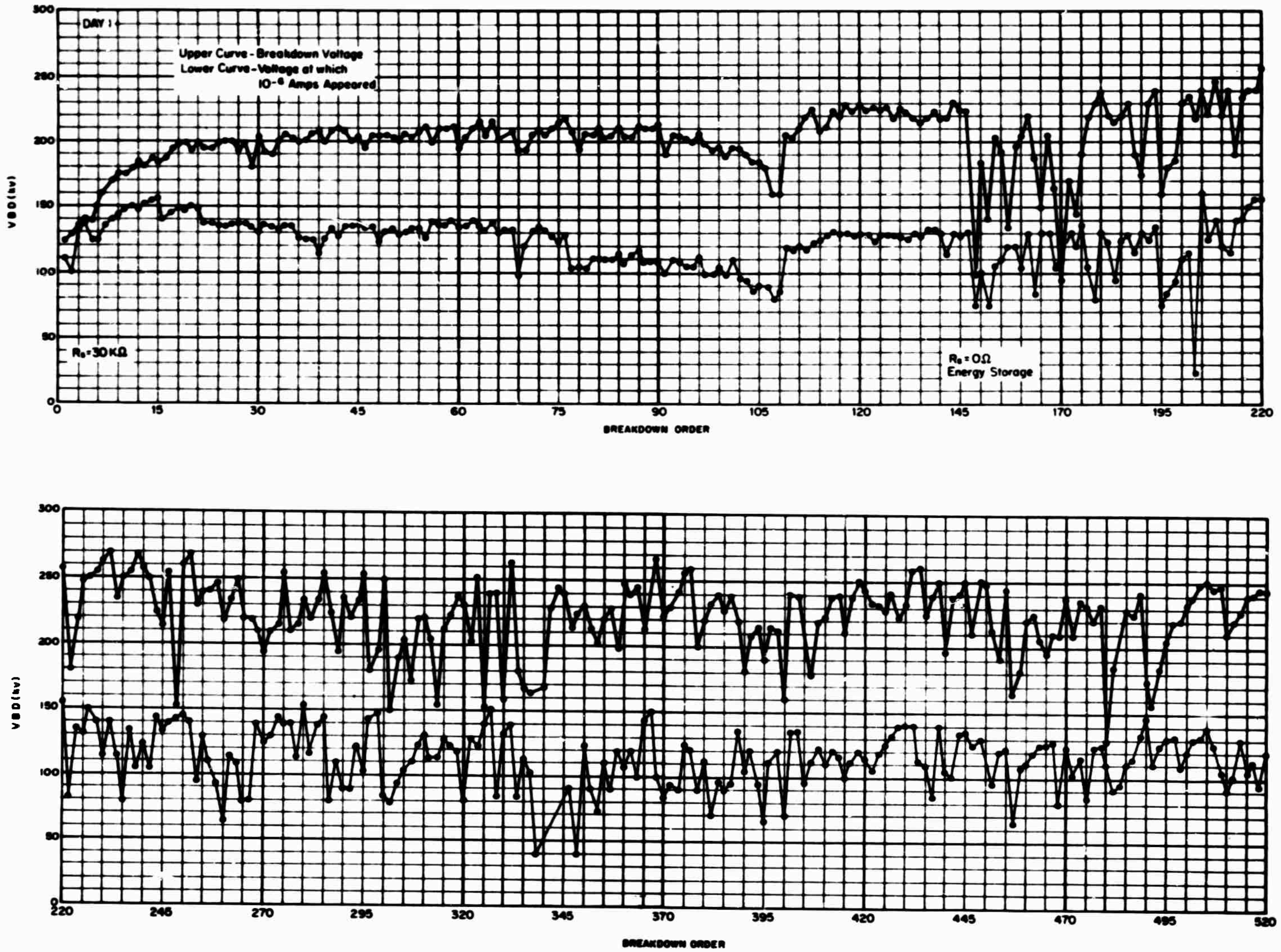
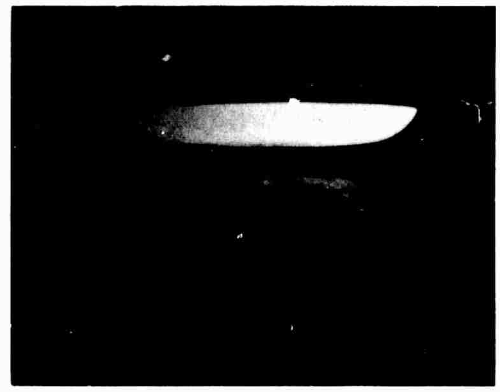


Figure 4. Conditioning Curve - Tungsten Anode and Ti - 7 Al - 4 Mo Cathode 2-Inches Diameter Uniform Field Electrodes at .75 cm Gap.

(a) Upper Electrode-Molybdenum Anode on Copper Mounting; Lower Electrode-Ti-7Al-4Mo Cathode



(b) Molybdenum Anode Glowing Red Hot (Note Reflection on Cathode)

(c) Front View of Molybdenum Anode After Testing

(d) Front View of Ti-7Al-4Mo Cathode After Testing

Figure 5 Molybdenum Anode vs Ti-7Al-4Mo Cathode Showing Limitations Imposed by Anode Heating

2-1458

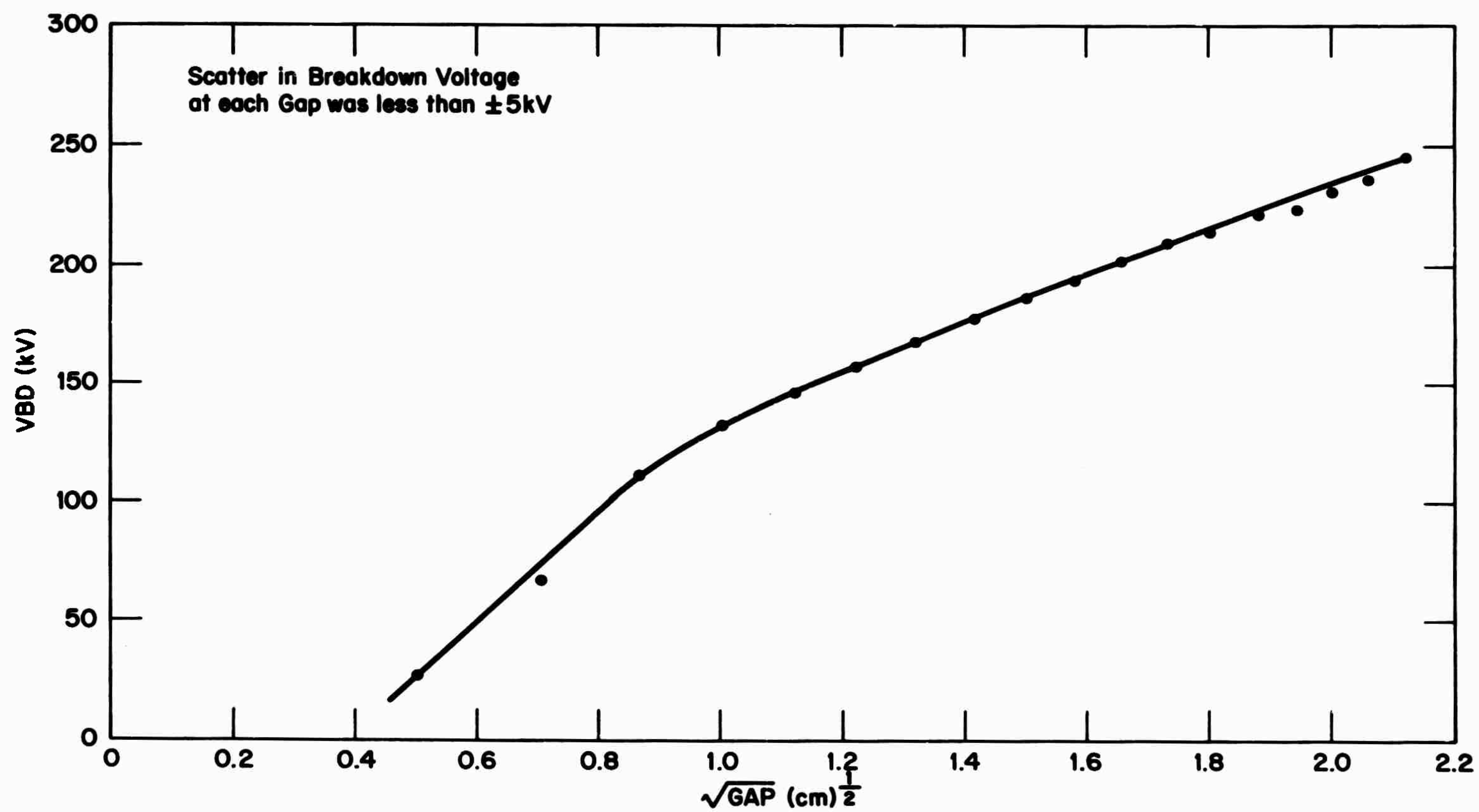


Figure 6. Breakdown Voltage versus Square Root of the Gap - 4-Inches Diameter Bruce Profile Electrodes - Lead Anode and Ti - 7 Al - 4 Mo Cathode - After Conditioning - Low Energy Discharges - Points are the Average of Nine Breakdowns.

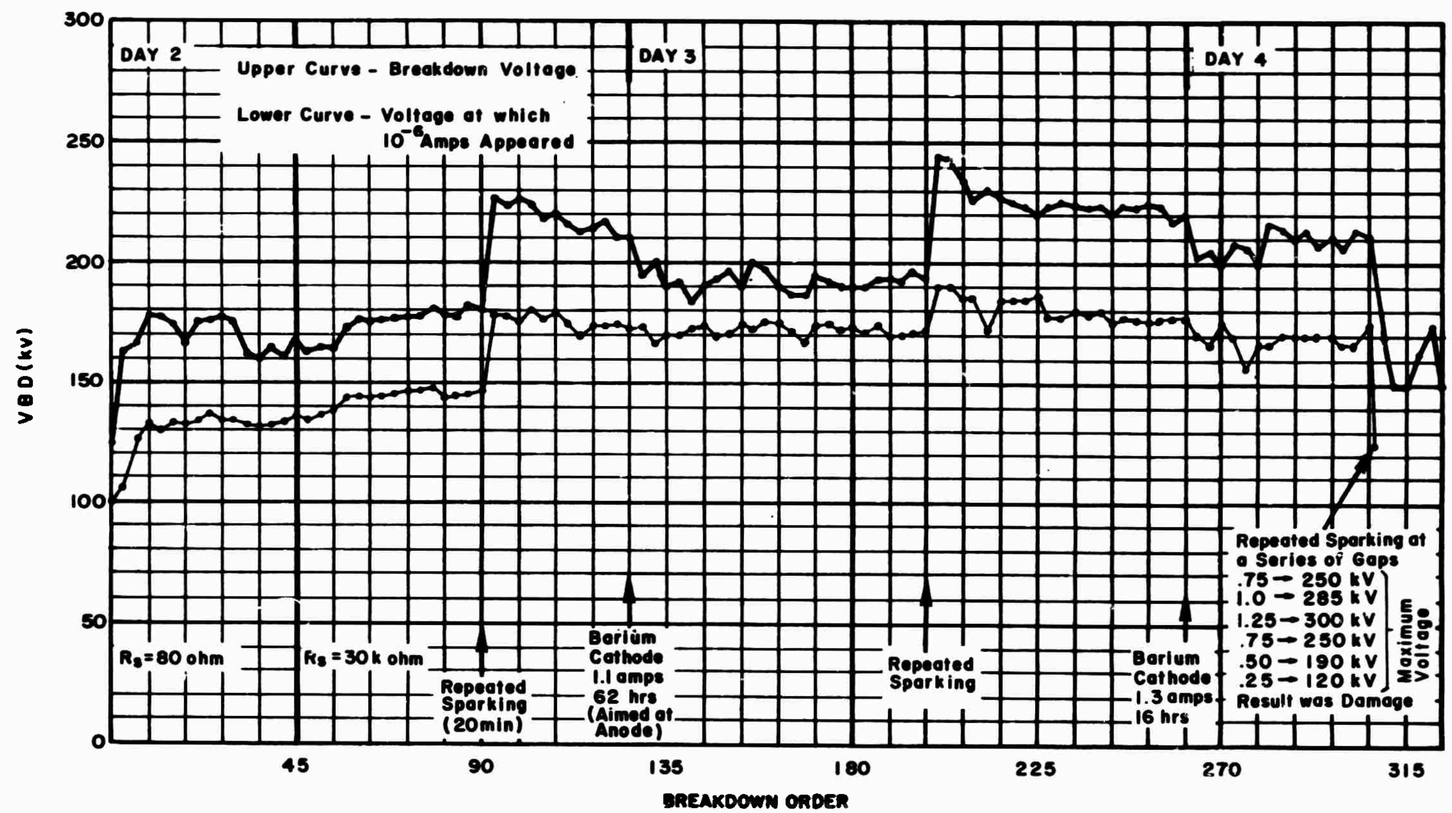


Figure 7. Conditioning Curve - 4-Inches Diameter Bruce Profile Electrodes Anode and Cathode OFHC Copper - Barium Contamination of Anode - Leak During Bake.

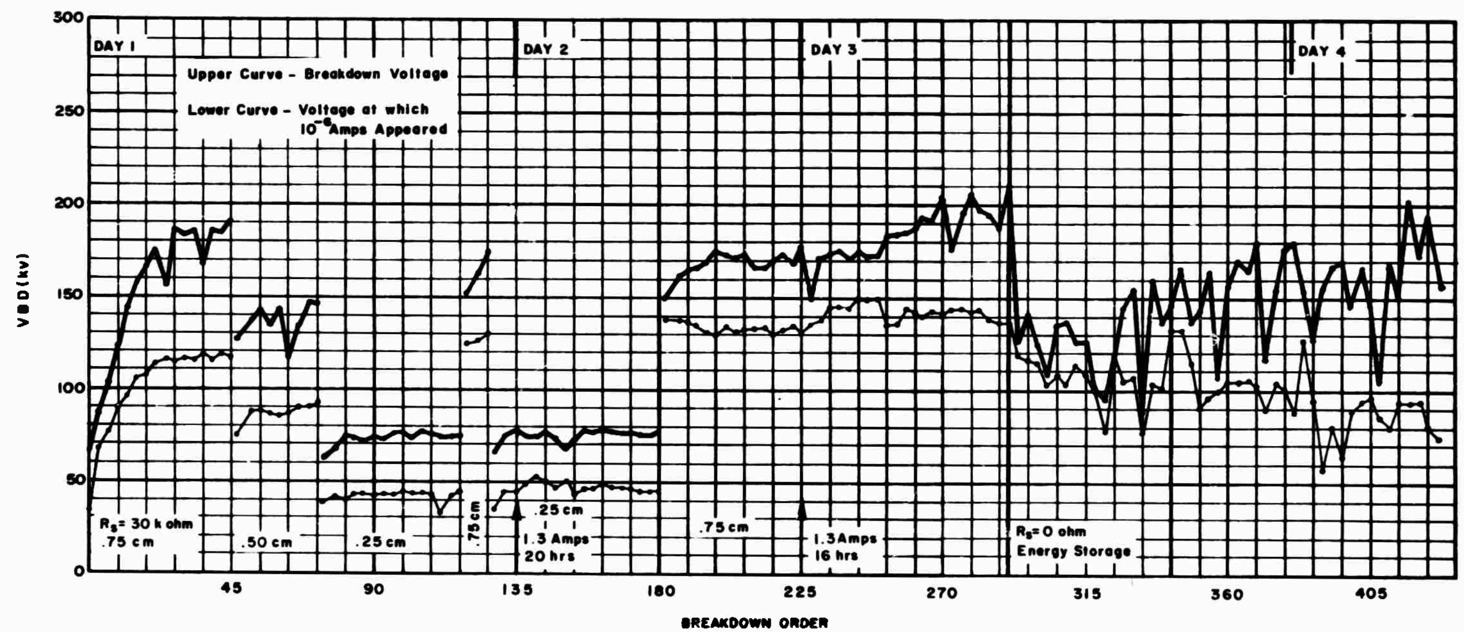


Figure 8. Conditioning Curve - 4-Inches Diameter Bruce Profile Copper Electrodes .25 and .75 cm Gap - Barium Contamination of Cathode.

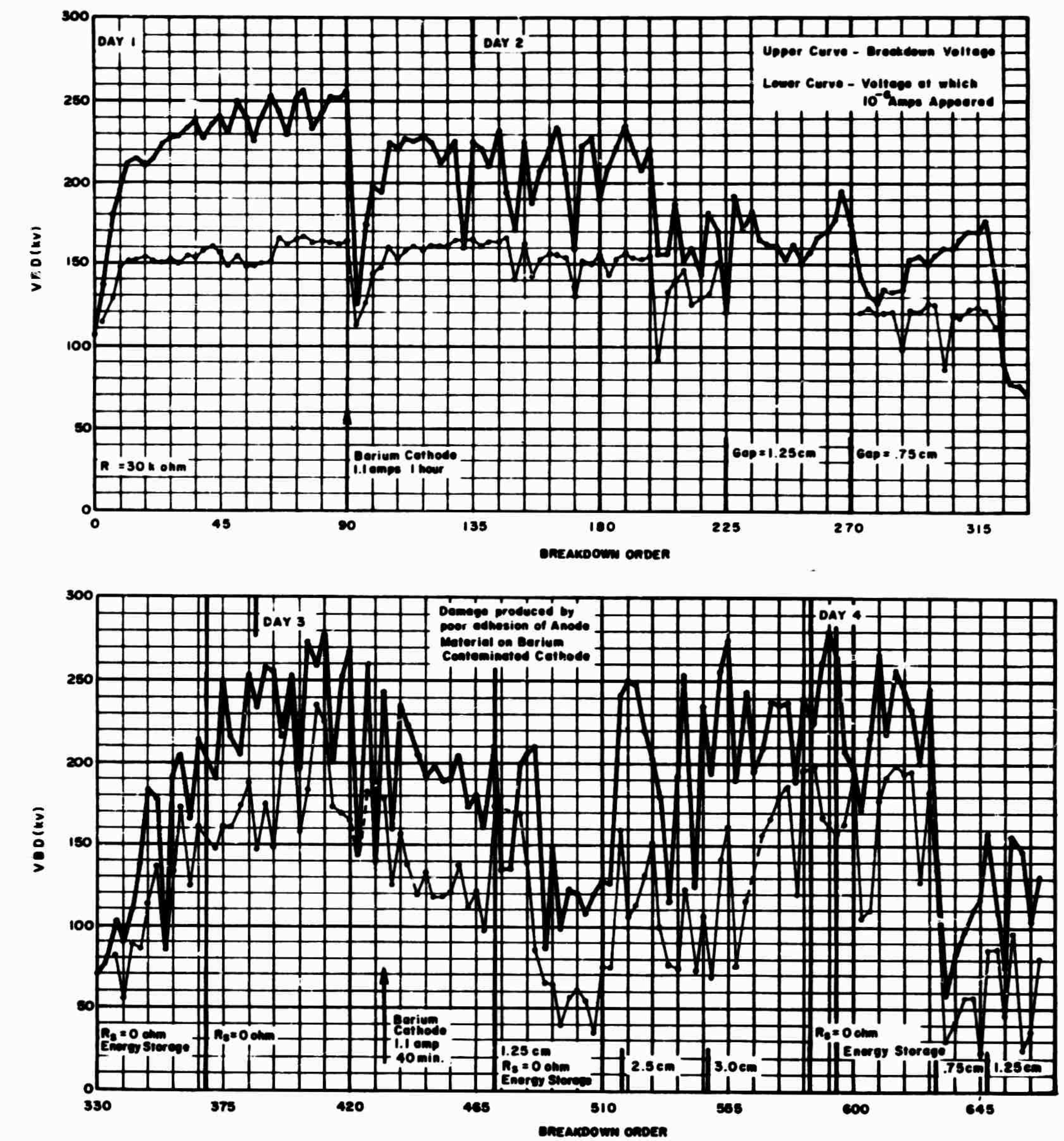


Figure 9. Conditioning Curve for 1.28-Inch Diameter Bruce Profile Electrodes of Nickel at .75 cm Gap with Heavy Barium Contamination of Cathode (at 2 mm).

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5. AUTHOR(S) *(Last name, first name, initial)*

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13. ABSTRACT The work reported ~~herein~~ describes a five-year program to study high voltage breakdown in vacuum and the factors which influence it with particular application to problems encountered in the development of high power vacuum tubes which operate in the range 100 to 300 kV.

Factorial and statistical design was used because it provided a powerful tool for the analysis of the results and enabled information to be derived from a minimum number of experiments on both the effects of the individual factors and on the degree of interaction among factors.

The test apparatus was designed and fabricated - bakeable vacuum chamber with control and monitoring apparatus (voltage, current, radiation and pressure).

Six major experiments were carried out: Preliminary, Pilot, Block of Eight, Block of Thirty-Two, Energy Conditioning and Barium Contamination Experiments. Factors studied included: Environmental Factors (residual gas, temperature, envelope, magnetic field, contamination, oxide films); Fields, Geometry and Area; Electrode Materials and Surface Properties; Electrical Circuitry, and Energy and Experimental Factors. The results are analyzed and discussed. ( )

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Electrical Breakdown in Vacuum						
Factors Influencing Vacuum Breakdown						
Prebreakdown Phenomena in Vacuum						
Criteria for Vacuum Breakdown						
Optical and X-Radiation						
Partial Pressure and Gap Current						
Factorial and Statistical Design						
Microdischarges						
Electric Field Enhancement and Etching						
Electron Beam Heating						
300 kV dc Test Apparatus						
Conditioning Procedures						
Energy Conditioning and Diversion						
Magnetic Field and Series Resistance						
Barium Contamination						
Electrode Materials and Surface Properties						
Electrode Firing and Gas Content						
Breakdown Voltage and Voltage Collapse						
Time and Area Effects						